Inferring the total ^{193}Ir(n,n')^{193m}Ir Cross Section

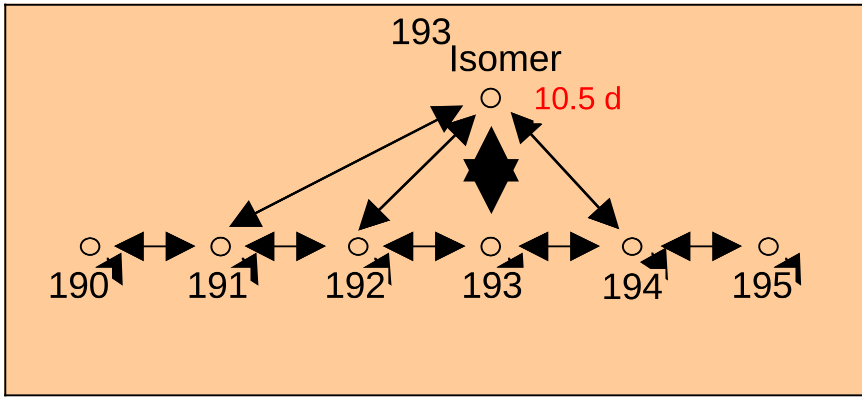
P.Talou[1], M.B.Chadwick[1], R.Nelson[2], N.Fotiades[2], M.Devlin[2], P.E.Garrett[3], W.Younes[3], J.A.Becker[3]
[1]*T-16, Los Alamos National Laboratory*
[2]*LANSCE, Los Alamos National Laboratory*
[3]*Lawrence Livermore National Laboratory*

Iridium isotopes are used as **radiochemical detectors**.

Isomer in ^{193}Ir: 11/2$^-$, 10.5 day (g.s.: 3/2$^+$)

The ^{193}Ir(n,n')^{193m}Ir reaction cross section can probe neutron fluences in the **few-MeV** neutron energy region (e.g. Fission neutrons).

Other (n,*x*n) reactions can probe higher-energy neutrons.

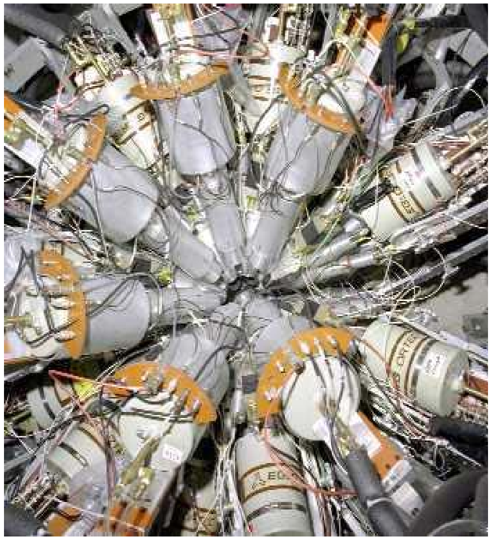


Status before this work: Experimental data (activation measurements by Bayhurst et al., 1975) for 4 energy points only.

→ New GEANIE/LANSCE (partial) data + modern theoretical calculations (GNASH).

A "Surrogate" Concept: Experiment measures part of the cross section, while theory is used to infer the missing (non-measured) remaining contributions.

Experimental data:



GEANIE 4π γ-rays detector

Activation measurements by Bayhurst et al. (1975) for four energy points only @ 7.57, 8.59, 9.34 and 14.7 MeV.

→ **GEANIE data**: measure of the partial cross section through the sum of discrete γ-lines feeding the isomer, from threshold up to >30 MeV.

→ Measurement of the 4 strongest discrete lines at: **219.2 keV**, **389.1 keV**, **398.8 keV** and **483.2 keV** feeding the isomer.

Theoretical Model Calculations:

→ **GNASH code** can calculate both **total** and **partial** cross sections for the Ir isomer.

The idea: *first*, validate model calculations through comparison with experimental information.
Second, use model predictions to correct experimental data for missing (non-measured) contributions.

→ Total isomer cross section:

$$\sigma(n,n') = \sigma\left(n, \sum 4\gamma\right)_{exp} \times \frac{\sigma(n,n')_{theory}}{\sigma\left(n, \sum 4\gamma\right)_{theory}}$$

Theoretical Modeling with the GNASH Code

Statistical Hauser-Feshbach Theory of the Compound Nucleus
+ Preequilibrium + Direct Reactions

Input Ingredients:

Optical Potential to infer elastic and reaction cross sections, and to provide transmission coefficients values to be used in HF decay equations.
Coupled-channels calculations: code ECIS96 (J.Raynal) used with OMP by. P.G.Young.
First three members of the g.s. rotational band explicitely coupled.

Nuclear Level Densities: Ignatyuk prescription, including a washing-out of shell effects in the level density with increasing energy.

$$a(U) = \alpha\left[1 + f(U)\delta W/U\right]$$

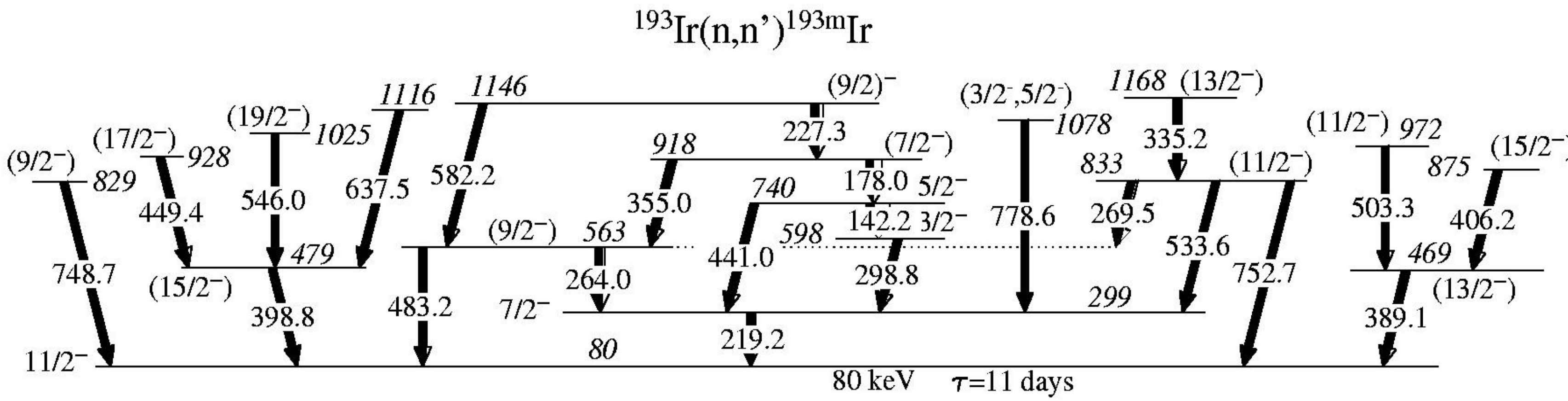
With

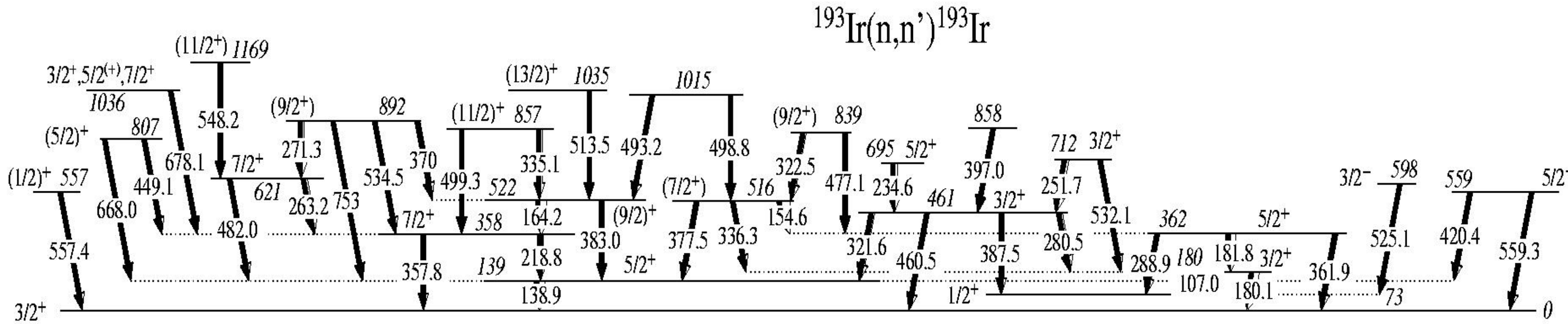
$$\delta W = M_{exp}(Z,A) - M_{ld}(Z,A,\beta)$$
$$f(U) = 1 - exp(-\gamma U)$$

(ld: liquid drop; β=deformation)

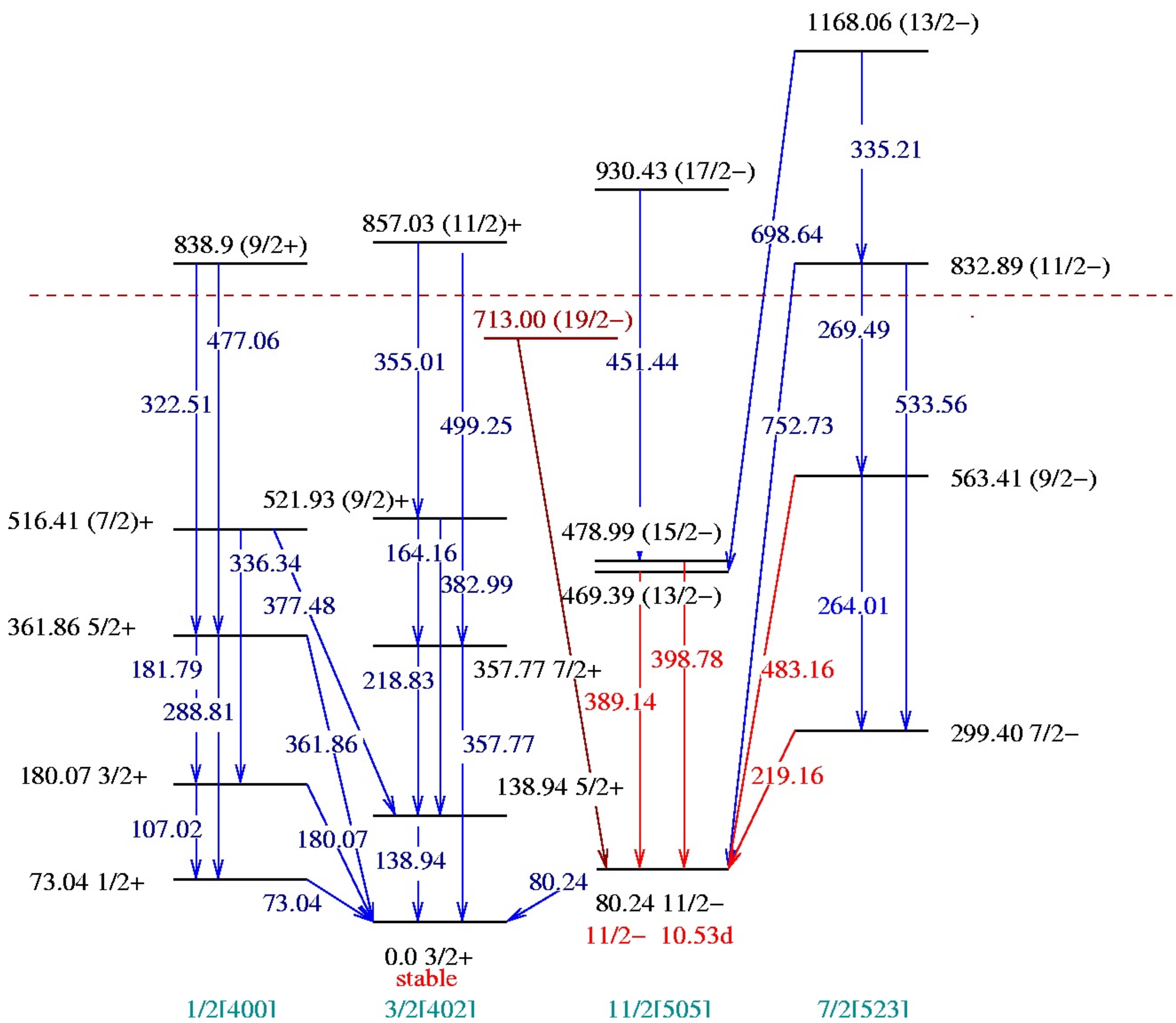
γ-rays strength function: generalized Lorentzian strength-function formalism of Kopecky-Uhl.
E1, M1, E2 radiations are included.

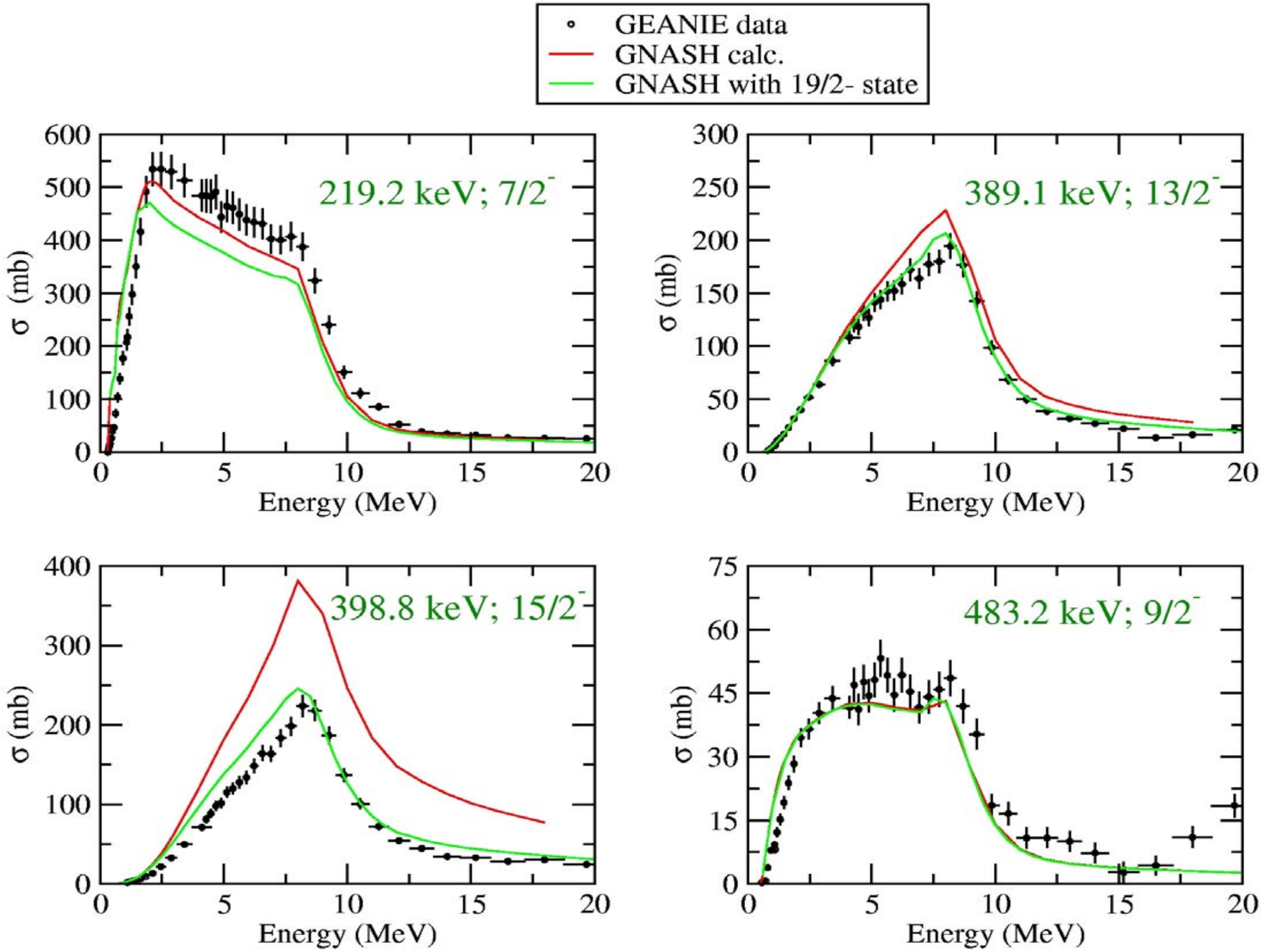
GEANIE observed levels





Partial level scheme in ^{193}Ir



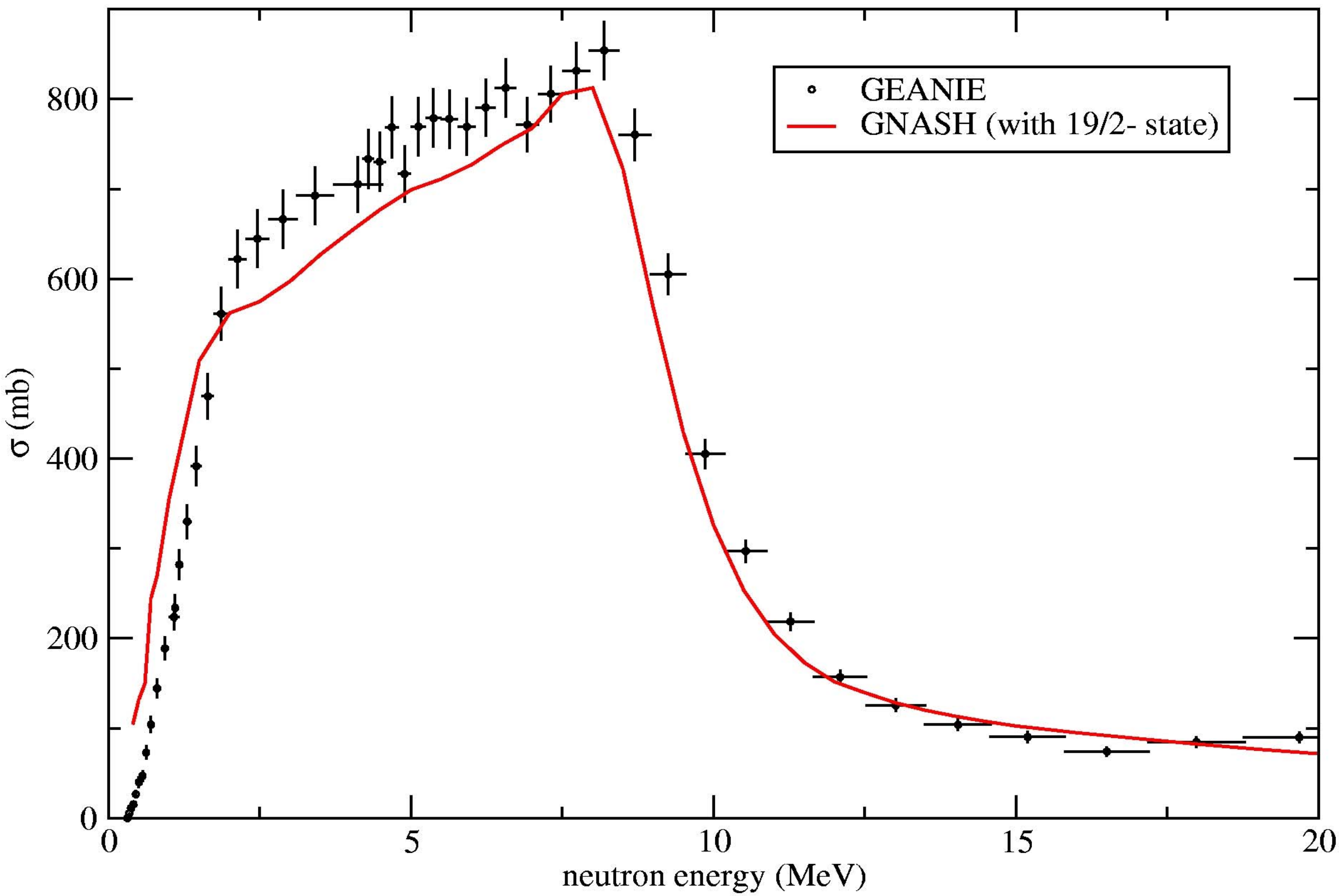


Experimentally, the excitation functions for the (very close in energy) $15/2^-$ and $13/2^-$ states are very similar in magnitude.

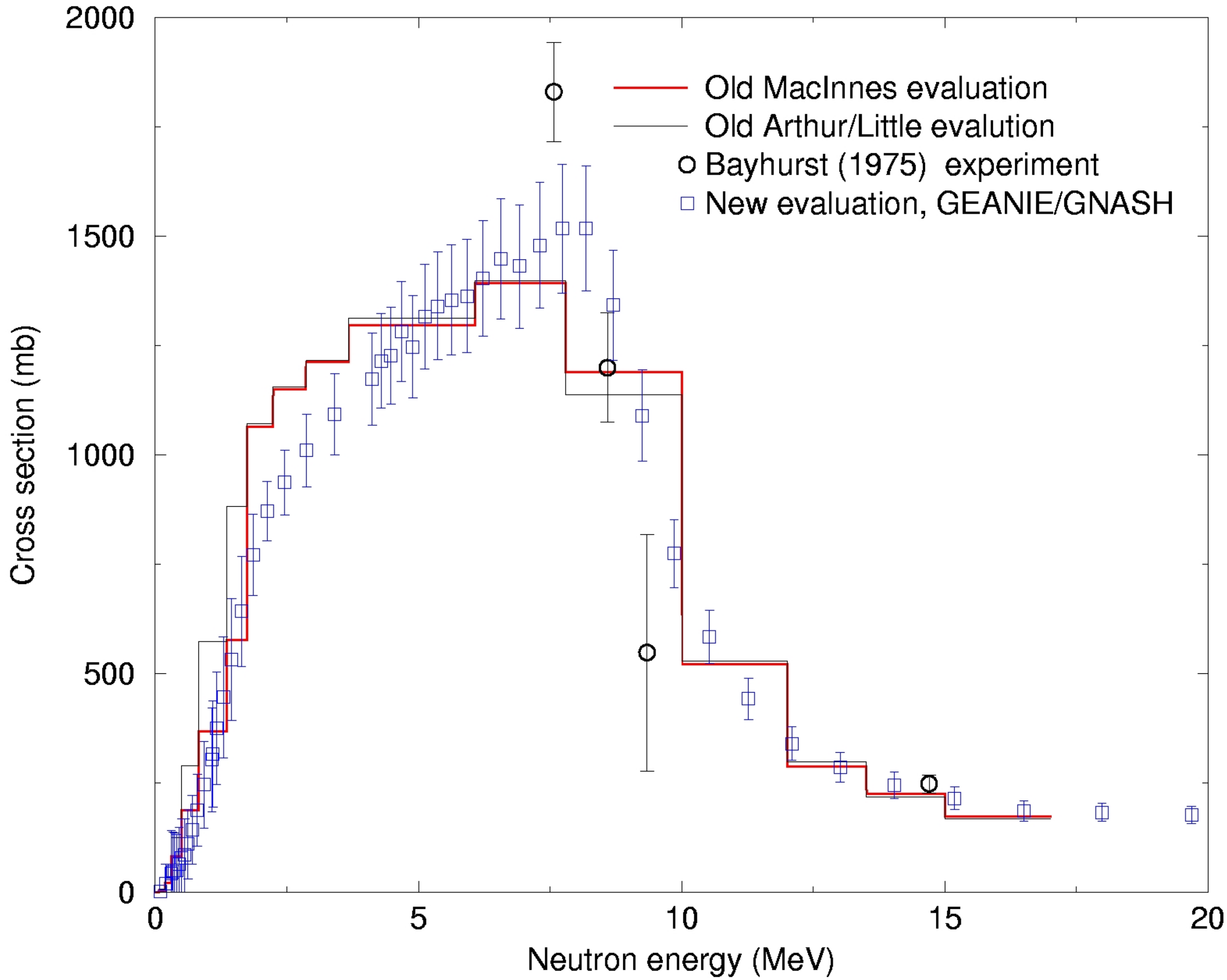
Theoretically, we can better reproduce this observation by ***postulating*** the existence of a high-spin state (above 600 kev) to redirect some of the flux feeding the $15/2^-$ state.

Sum of 4 observed γ-discrete lines

219.2, 389.1, 398.8, and 483.2 keV

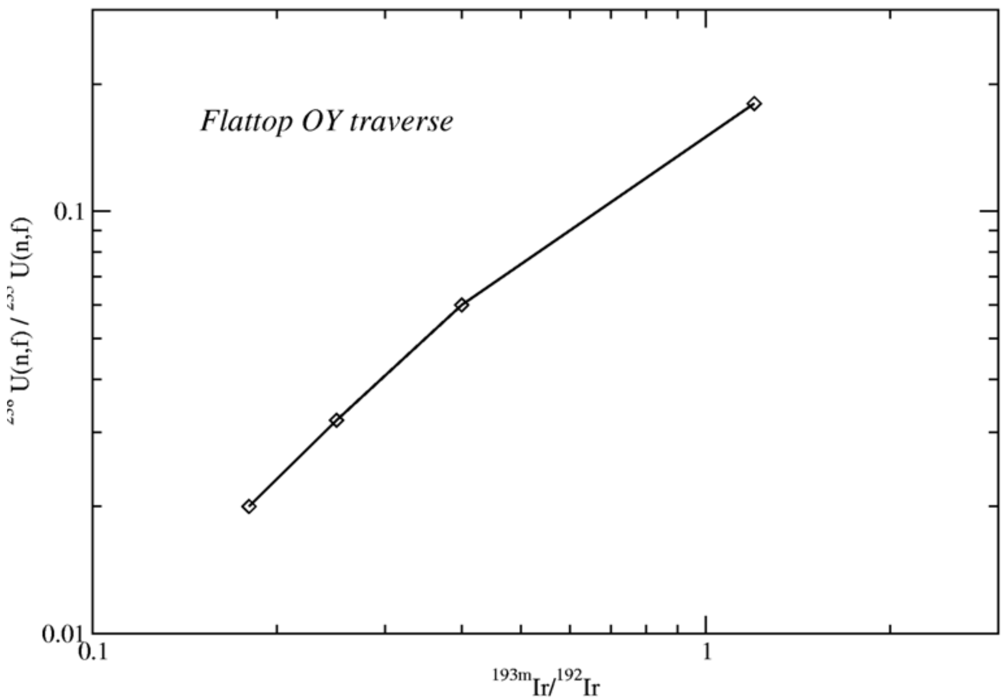


Ir193 (n,n') isomer

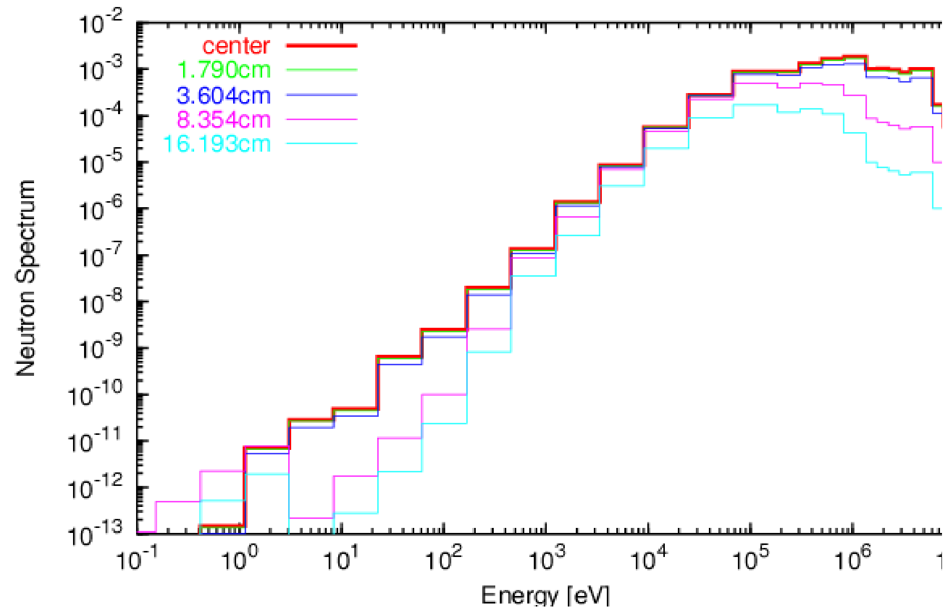


Integral Data Testing

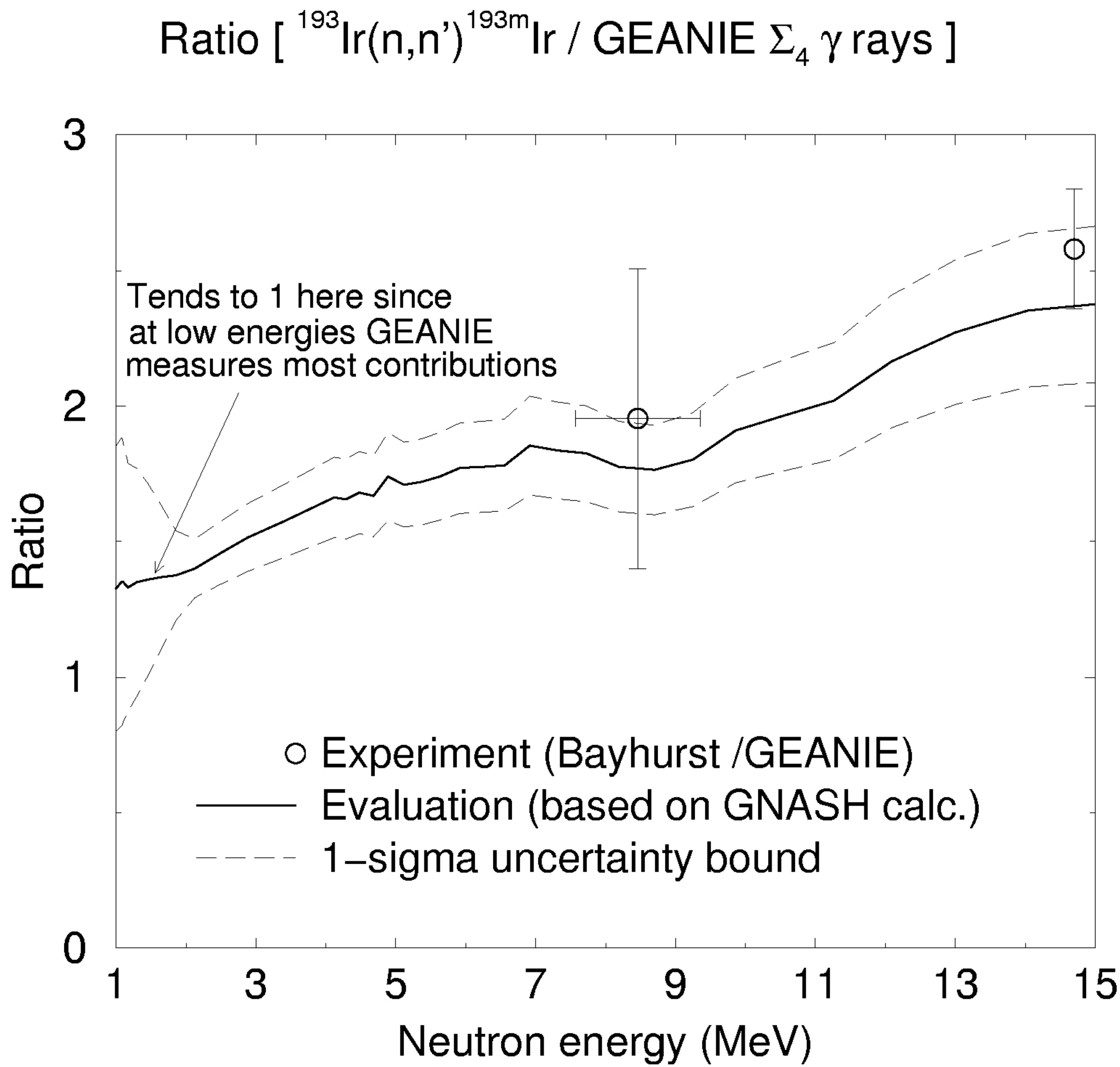
→ Critical Assemblies such as Flattop can be used to test this reaction cross section through integral measurement (cross section folded with neutron spectrum).



Flattop (transverse) Neutron Spectrum



New (n,n') cross section validates the *ad hoc* ansatz of MacInnes @ low energies.


Ratio [^{193}Ir(n,n')^{193m}Ir / GEANIE Σ_4 γ rays]
3
2
1
0
Ratio
1
3
5
7
9
11
13
15
Neutron energy (MeV)
Tends to 1 here since
at low energies GEANIE
measures most contributions
Experiment (Bayhurst /GEANIE)
Evaluation (based on GNASH calc.)
1−sigma uncertainty bound

γ-rays transitions to the ground-state ?